EXTENDED TEST REPORT OF THE BALLAST WATER MANAGEMENT SYSTEM OF COLDHARBOUR MARINE LTD.

SCIENTIFIC BACKGROUND AND MOTIVATION FOR DEVIATIONS FROM GUIDELINE G8

Prepared by

MEA-nl B.V.

Den Oever, The Netherlands

Marine Eco-Analytics-nl

info@mea-nl.com

Date: November 2013

MEA-NL

MARINE ECO ANALYTICS

This report has been prepared under the MEA-nl Quality Management system. The Quality Management System in accordance with the ISO-9001:2008 standard of MEA-nl is certified by UKAS and periodically audited by Lloyd's Register.

Quality Management: ISO 9001:2008

Den Oever, November 2013

Sluiskolkkade 2
1779 GP, Den Oever
The Netherlands

Version 1.4
Project number: 10110.02

Water and sediment of ships should be free of potentially invasive organisms

There is no wisdom without ballast

Content

List of figures

List of tables

1. EXECUTIVE SUMMARY

1.1 PURPOSE AND RESULTS

The final verification report on the Ballast Water Management System (BWMS) of Coldharbour Marine Ltd. is based on the verification procedures described in guideline G8 of IMO (Anon., 2008) for the certification (Type Approval) process, and the GVP (EU-ETV pilot program, version 1.0 December 2011). This extended, internal data report is a supplement. It aims is to present the reasons for deviations from guideline G8 and to explain data interpretation.

From 14th of June until the 09th of September 2013, the Coldharbour BWMS, underwent the required land-based testing at the test barge of MEA-nl (The Netherlands). During this period 10 consecutive, successful test cycles have been completed. These tests were conducted in the Dutch Wadden Sea. They covered a salinity range from 19.8 to 34.6 PSU. Organism numbers on intake were for most test runs well above the requirements (Anon, 2008). The performance of the treatment technology did meet the IMO D2-discharge standard (IMO, 2004) for organisms after a eleven-day holding period. Control tanks showed sufficient survival to demonstrate the BWMS capabilities. The measurements indicated that the BWMS was effective in reducing the number of live organisms as classified in regulation D2 (IMO, 2004).

1.2 ACKNOWLEGDMENTS

The authors thank the technical staff of the MEA-nl barge as well as the crews of the tug-boats “Mazzel” and “Jan van Hasselt sr.”. We thank Mr J. Witte and Mr A. Smit. We also like to thank Mr M. Wells, Mr W. Christie, Mr P. Orwin, Mr A. Birkinshaw, Mr N. Towers, Mr S. Radford, Mr J. Christie, Mr M. Rand and Mrs N. Wise, for their excellent collaboration during the testing process.

2 INTRODUCTION

The present report is a supplement to the formal verification report that will be submitted as part of the documents for certification. Its structure follows the verification report but it provides background information that will enable the Recognized Organization on behalf of the respective national administration to evaluate the whole testing procedure rather than the data alone. The present report presents the motivations and interpretations of MEA-nl. An interpretation of a fact by default makes it an opinion, as opposed to a neutral observation. As such it seems unsuited for the final verification report, hence this supplement.

2.1 PORTRAIT COLDHARBOUR MARINE LTD., DESCRIPTION OF THE BALLAST WATER TECHNOLOGY SYSTEM AND PERFORMANCE CLAIMS

Coldharbour Marine Ltd is a UK based Marine Engineering Company with more than 35 years of experience in the marine sector.

The Coldharbour Marine BWMS works as an in-tank treatment system as opposed to most other systems that treat in-line. The Coldharbour system does not include a filtration step. Treatment starts only after the ballast-tank has been filled. Therefore its performance and scalability are not related to the flow rate of the ballast water, but to the size and shape of the ballast tank.

Treatment is based around the injection of "inert" gas into the tanks. This inert gas injected contains a maximum of 0.2% oxygen. Though termed "inert" in compliance with standard industrial practice, the gas contains more carbon dioxide than normal air. Subsequently it lowers the pH of the treated water considerably due to the formation of carbonic acid. The de-oxygenation in combination with the lowered pH is one component of the treatment process. The second component is formed by injecting the gas as micro-bubbles and subsequently disrupting them using ultrasonic energy. Prior to discharge the treated water is aerated in order to elevate the pH and the oxygen content of the water back to environmentally safe values.

Due to the very different physical and chemical properties of pure fresh-water as compared to brackish and full marine water, the system to date has only been verification tested for the latter two types of water.

2.2 TEST ORGANISATION MARINE ECO-ANALYTICS-NL (www.mea-nl.com)

MEA-nl was established in 2012 by its three initiators (Mr. E. Brutel de la Rivière MSc., Dipl. Biol. F. Fuhr and Dr. M. Veldhuis PhD). All three are having a long standing record in ballast water treatment research, testing and verification.

MEA-nl is an expert centre for a broad field of research related to introduction vectors of alien invasive species in marine and fresh-water ecosystems. MEA-nl is focussing on a wide range of introductory routes not only on ballast water from ships, but also bio-fouling and aqua culture. MEA-nl provides a broad field of expertise rendering our team an excellent partner to assist developers of water-disinfection technologies in feasibility and field studies for their projects. MEA-nl also supports ship-owners, port-authorities, aqua- and marine-culture facilities and policymakers as to upcoming responsibilities in view of minimising and ultimately preventing alien invasive species introductions.

The current focus is in particular on R&D as well as verification testing of Ballast Water Management (BWM) systems for ship-board application. Testing of BWM systems is conducted on-board of the research and test vessel MEA-INNOVATOR (fig. 1). Verification testing is always conducted in close collaboration with a national administration or its representative (classification society) as the Recognized Organisation. For the verification procedures of ballast water management systems, the Quality Management System of MEA-nl in accordance with the ISO-9001:2008 standard, is certified by the United Kingdom Accreditation Service (UKAS) and periodically audited by Lloyds Register (ISO 9001:2008).

Figure 1: aireal view of the test barge MEA-INNOVATOR passing the locks between the Wadden Sea and Lake Ijssel

Unlike shore facilities the test barge of MEA-nl offers the flexibility to change conveniently between water regimes (fresh and brackish up to 32 PSU). Each has different characteristics in terms of physical, chemical and biological properties. This allows to test representatively for most water conditions encountered by ships while ballasting.

2.3 RECOGNIZED ORGANISATION (RO)

Lloyds' Register (LR) is acting as a Recognised Organisation on behalf of the Maritime and Coastguard Agency (MCA), United Kingdom, for the witnessing of land-based testing, shipboard testing, type approval documentation review and certification of Coldharbour Marine Ltd. BWMS in accordance with guideline G8 (Anon., 2008).

3 CONDITIONS FOR LAND-BASED TESTS

3.1 REGULATION D-2

Regulation D-2 of the Ballast Water Management Convention (IMO, 2004) stipulates that ships meeting the requirements of the Convention by meeting the ballast water performance standard must discharge:

1. *less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension;*
2. *less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension; and*
3. *less than the following concentrations of indicator microbes, as a human health standard:*
    - *Toxicogenic Vibrio cholerae (serotypes O1 and O139) with less than 1 Colony Forming Unit (cfu) per 100 millilitres or less than 1 cfu per 1 gramme (wet weight) of zooplankton samples;*
    - *Escherichia coli less than 250 cfu per 100 millilitres; and*
    - *Intestinal Enterococci less than 100 cfu per 100 millilitres.*

3.2 LAND-BASED EXPERIMENTAL DESIGN

The MEA-INNOVATOR is a modified barge exclusively designed to accommodate a broad variety of BWM systems or alternative treatment options (fig. 1). The ship has a capacity of 10 holding tanks, varying in content from 184 to 236 m^3. It can accommodate multiple systems at the same time.

The in-tank part of the equipment of Coldharbour was installed in the two hindmost tanks (Starboard 5 and Portside 5). These tanks have a capacity of 221 m^3 each and were used exclusively for Coldharbour throughout the whole testing period. Tanks were coated with standard ballast water tank coating (International Paint - Intershield 300). No amendments, to the challenge water were made in the present land-based verification program. Water quality, in terms of physical, chemical and biological parameters however, changed as part of seasonal variations encountered during the test season. Water conditions (Wadden Sea) varied in terms of salinity between 19.8 and 34.6 PSU (table 8). For each test run the barge was moved to the appropriate water condition (fig 2).

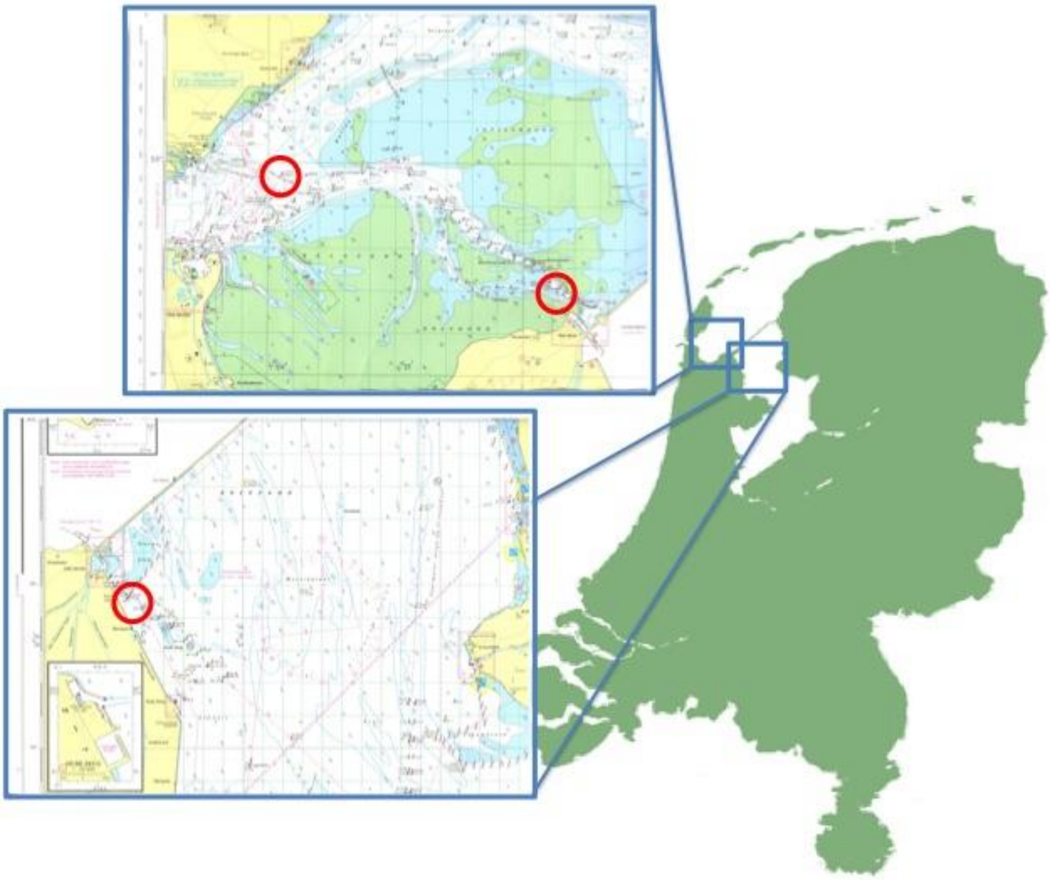

Figure 2: Location of test area in the larger context of the North Sea; insert: locations of the fresh water (Lake Ijssel) and brackish water (Wadden Sea) test sites

During intake challenge water was pumped into different tanks. Two of these were treated independently and acted as one separate test run each. Depending on circumstances one or two more tanks were filled as control. A schematic overview of pumping operations can be found in figure 3 for intake and figure 4 for discharge operations.

Water was stored for a holding period of eleven days prior to discharge (table 1). This was a deliberate deviation from the minimum required holding time of five days as described in guideline G8 (Anon., 2008). The system was designed for large vessels with longer storage times of ballast water. In consultation with the Principal and approved by LR, it was agreed to test the system with a longer holding time.

For analysis a variety of continuous or discrete samples are taken during the process of intake and discharge at appropriate sample points. This first-line analysis is done on-board of the MEA-INNOVATOR in a special designed laboratory container. Details can be found in the test-protocol (Anon., 2012) and an overview in section 3.3.3 of this report.

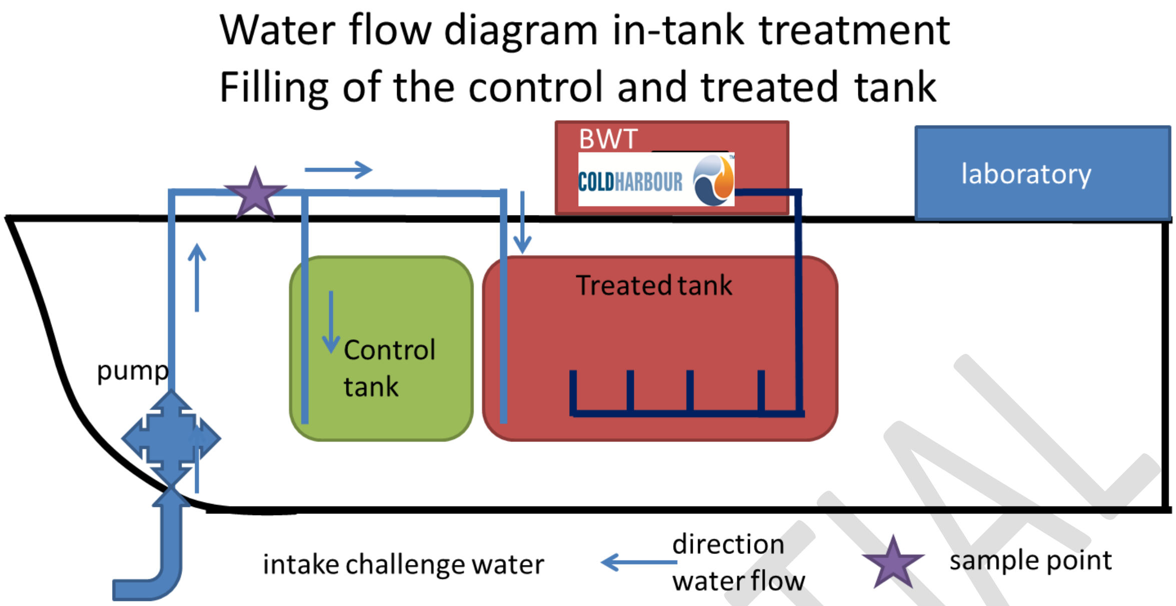

Figure 3: schematic overview of water flow at intake in the control and treated holding tank and position of sample point.

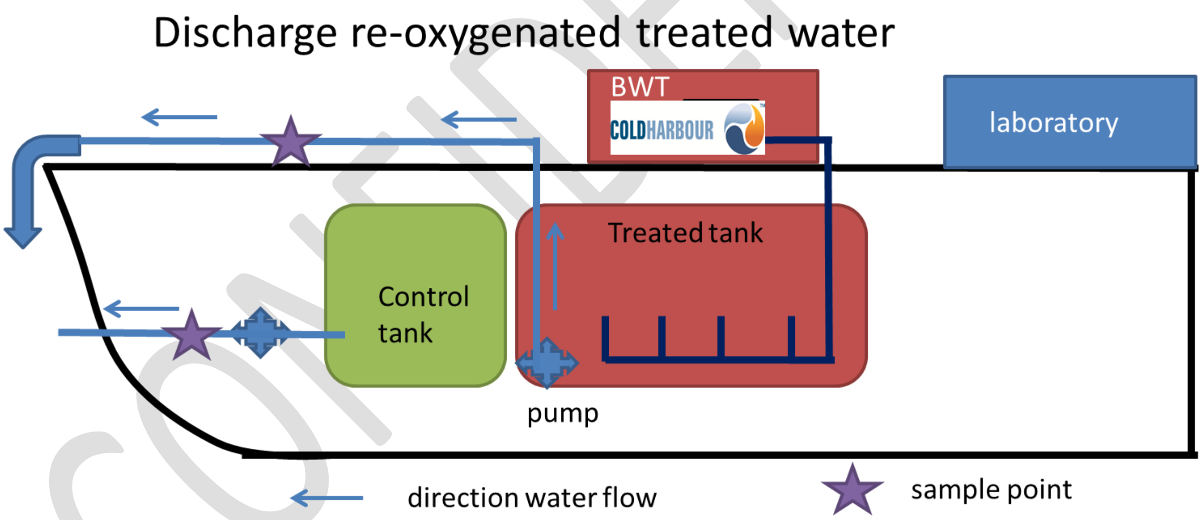

Figure 4: schematic overview of water flow during discharge from the control and treated holding tank and position of sample points

Table 1: Intake and discharge dates for each certification test run. Only G8 relevant test runs are listed, with numbers VIII and lower, XVII and XVIII being R&D runs conducted outside the scope of this report

Test run	intake	discharge
IX	14-06-2013	25-06-2013
X	14-06-2013	25-06-2013
XI	27-06-2013	08-07-2013
XII	27-06-2013	08-07-2013
XIII	11-07-2013	22-07-2013
XIV	11-07-2013	22-07-2013
XV	25-07-2013	05-08-2013
XVI	25-07-2013	05-08-2013
XIX	29-08-2013	09-09-2013
XX	29-08-2013	09-09-2013

All tests were conducted in pairs, i.e. intake and discharge on the same dates, but as two seperated test runs. To this end portside and starbord tanks were treated independently of each other after filling.

Prior to the verification test series a number of R&D test runs were performed, including fresh water tests. These tests were performed in the period of February 19th to May 13th, 2013. From August 8th to August 19th, 2013 two fresh water test runs were performed due to the schedule of the barge (XVII & XVIII, data not shown). These tests were scheduled as R&D tests and did not form part of the verification test series. In 2012 an additional series of six fresh water test runs was performed.

3.3 CHALLENGE WATER

3.3.1 PHYSICAL AND CHEMICAL CONDITIONS

The following quality characteristics of the challenge water are required by guideline G8 (Anon., 2008) for land-based tests (table 2).

Table 2: salinity ranges and minimum concentrations of TSS, POC, and DOC in the challenge water as required by guideline G8 (Anon., 2008; section 2.3.17)

Parameter	Salinity			unit
	<3 PSU	3 – 32 PSU	> 32 PSU	
Total Suspended Solids (TSS)	> 50	> 50	> 1	mg/L
Particulate Organic Carbon (POC)	> 5	> 5	> 1	mg/L
Dissolved Organic Carbon (DOC)	> 5	> 5	> 1	mg/L

Guideline G8 (Anon., 2008; section 2.3.18) requires tests to be performed at two out of the three defined salinity ranges. If testing in two adjacent ranges, challenge water should differ by at least 10 PSU. This is to avoid testing at, e.g. 31.5 PSU as brackish and subsequently 32.1 for high salinity. We deviated from this requirement based on the following considerations: In other test series conducted in the Wadden Sea, intake water was manipulated to be in accordance with the requirement. Fresh water or brine solution was added to test at around 20 and just above 32 PSU respectively. While this approach was perfectly in line with the guideline, it did not add any information for systems that were not influenced by such salinity changes as encountered in coastal areas, i.e. highly variable salinities but not below 5 – 10 PSU. In consultation with the Principal and LR it was concluded, that Coldharbour's BWMS is not influenced by salinity changes in marine environments. This was also seen in the experimental test runs prior to the certification tests (data not shown). Therefore it was decided to not manipulate the test water in order to minimize unnecessary (osmotic) stress for the organisms during the elongated holding period. Keeping the organisms in their ambient water was considered more important for the replicability and reliability of the data than manipulating salinity. Instead the system was tested at two different locations in the Wadden Sea (fig. 2). This resulted in a salinity range encountered during the tests from 19.8 to 34.6 PSU (table 8).

3.3.2 BIOLOGICAL CONDITIONS

Table 3 shows the minimal numerical abundance at intake as required in guideline G8 (Anon., 2008). Especially for marine environments these target numbers are high. Even in the Wadden Sea, one of the most productive marine areas in the world, it is difficult to find that many organisms for the time span required to complete certification testing.

Table 3: Minimal numbers and species diversity required at intake for different size classes and groups of organisms in guideline G8 (Anon.,2008; section 2.3.20)

challenge water		
Parameter	**unit**	**Remarks**
organisms ≥ 50 micron	> 10^5/ m^3	at least 5 species from at least 3 different phyla/divisions
10 ≤ organism size ≤ 50 micron	> 10^3/ mL	at least 5 species from at least 3 different phyla/divisions
< 10 micron[1]		
heterotrophic bacteria	> 10^4/ mL	not further defined

[1]: For completeness, quantification of the planktonic fraction (phytoplankton and other protists < 10 µm) is also included in the tests program conducted by MEA-nl.

No additions of surrogate organisms were made and as a result of natural variability during some test runs intake values were less than the target number (tables 14 and 15).

3.3.3 SAMPLING METHODOLOGY

A detailed description of sampling and analytical methods applied is given in the Coldharbour Marine Ltd BWMS test protocol (Anon., 2012). Table 4 shows most parameters as well as regular sample volumes according to different standards. Table 5 shows which analysis is performed by whom (MEA-nl or sub-contractor), where and according to which standard. Sections 3.3.3.1 through 3.3.3.4 elaborate on motivated deviations from the standard procedure. Most of these deviations are related to the sampling on intake and the fact that the BWMS is an in-tank rather than in-line treatment.

Table 4: List of core parameters, sample volume according to IMO and ETV test protocols and procedure followed at the *MEA INNOVATOR*

Sample volumes of treated and control water			
Parameter	**Volume IMO**	**Volume ETV**	***MEA INNOVATOR***
pH, Salinity, temperature, TSS, POC, DOC, DO, turbidity (standard parameters)	10 L	TSS: 100 mL POC:500 mL DOC: 25 mL DO: 300 mL	In triplo 10 L bucket samples evenly distributed over the whole sampling period, sample size varies depending on particle load (SOP-306, 308)
Inorganic nutrients		500 mL	N, P from filtrate Si directly from bucket sample (SOP-308)
10 ≤ organism size <50 micron	10 L	3 m^3 concentrated to 1000 mL	samples taken in triplicate at same time as standard parameters (1 L) (SOP-317, 318 & 319)
heterotrophic bacteria	500 mL	1000 mL	samples taken in triplicate at same time as standard parameters (1 L) (SOP-316)
organisms < 10 micron	n.a.	n.a.	samples taken in triplicate at same time as standard parameters (1 L) (SOP-322)
organism size ≥ 50 micron; treated water	1 m^3	3 m^3 concentrated to 1000 mL	Continuous subsampling, covering whole sample period. Total of 3 times 1 m^3 (SOP-320)
organism size ≥ 50 micron; control water	20 L		3 bucket samples of 20 L each, at same time as standard parameters (SOP-320)

Table 5: Analyses with their associated measurement standard, equipment and MEA-nl SOP-number

On site (laboratory *MEA-INNOVATOR*)	SOP-MEA-nl	Equipment/standard
salinity, temperature, pH, dissolved oxygen and turbidity	SOP-306	Handheld meter (e.g. Palintest Macro 900)
Organisms <10 µm phytoplankton	SOP-322	Flow cytometry
Organisms 10-50 µm	SOP-317	Flow cytometry
Organisms 10-50 µm	SOP-318	PAM-fluorometry
Organisms >50 µm	SOP-320	Microscopy
Incubation experiments	SOP-326	Flow cytometry/PAM-fluorometry
Organisms <10 µm bacteria	SOP-316	Flow cytometry
Off site (laboratory MEA-nl)		
Organisms 10-50 µm Microscopy	SOP-319	Inverted Microscopy
TSS/POC and MM (filtration will be on site)	SOP-309	Filtration
External		
Human Pathogens	SOP-311	ISO-7899-2, ISO 9308-1
Dissolved nutrients (nitrogen, phosphate, silicate)	SOP-308	Internal standard of subcontractor based on international standards
Dissolved Organic carbon (DOC)	SOP-308	NEN-EN 1484

3.3.3.1 ABIOTIC PARAMETERS

Sampling and measurement of abiotic parameters mostly followed the standard procedures described in the test protocol (Anon., 2012) and table 4. Since all tanks were filled at the same time, number of samples on intake were reduced sometimes, i.e. four samples within one hour, covering the whole pumping period for two tanks, rather than 3 samples per tank. If the first and second reading of the standard parameters temperature, pH, salinity, dissolved oxygen and turbidity indicated a change of water masses, sampling frequency was increased. If the readings were consistent, four samples were deemed sufficient to define the intake water properly.

3.3.3.2 ORGANISMS IN THE SIZE CLASS LARGER THAN 50 MICRON

On intake discrete samples of 20 litres each were taken. Since the Coldharbour BWMS is an in-tank treatment that does not start treating the water during pumping, no samples for treated T0 were taken. This is a deliberate deviation from guideline G8 (Anon., 2008) since the guideline on this point was clearly written with in-line treatment in mind. On discharge, covering the whole pumping period, three continuous but consecutive samples of 1 m^3 each are taken of the treated water. Three discrete samples are taken for the control. All samples were concentrated and counted in whole immediately after sampling. No subsampling is performed on the samples for this size class. Viability was assessed by visual inspection and physical manipulation ("poking") to check motility.

3.3.3.3 *ORGANISMS IN THE SIZE CLASS FROM 10 TO 50 MICRON*

Covering the whole pumping period discrete samples of 1 litre were taken together with the standard parameters. Of each bottle three subsamples were counted life applying flow cytometry, which also included phytoplankton smaller than 10 micron. Inspection of other protists (i.e. microzooplankton) was done using preserved samples taken at the same time as the life samples (1L each). Analysis was done by inverted microscopy.

The viability of the phytoplankton community was determined by measuring the photosynthetic efficiency of the phytoplankton.

This set of measurements was also done during incubations of 10L sampling water, of intake and discharge, for a period of at least 5 days (table 15). Incubations were followed to monitor potential regrowth under optimal environmental conditions.

3.3.3.4 *BACTERIA*

The total number of (free) heterotrophic bacteria was analysed by staining the nuclear DNA and counting by flow cytometry. This was done with samples taken at the same time as the standard parameters. The relevant human pathogens (*E. coli* and enterococci) were analysed by an accredited laboratory (VITENS b.v.). *Vibrio cholera* of the two types relevant to ballast water testing do not occur in Dutch coastal waters. They are therefore not part of the present study.

4 RESULTS LAND-BASED TESTING

After a series of research and commissioning test runs, a total of 10 test runs for certification purpose were conducted in the Wadden Sea.

4.1 ABIOTIC PARAMETERS

Guideline G8 (Anon., 2008; section 2.3.25) calls for the measurement of eight abiotic parameters. They are pH, temperature, salinity, dissolved oxygen (DO), total suspended solids (TSS), dissolved organic carbon (DOC), particulate organic carbon (POC) and turbidity. Data can be found in the following tables 6 through 13.

Table 6: Average of pH for individual runs at intake (T0) and discharge (T11)

pH				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	8.2	as Control	8.1	6.6
X	8.2	as Control	8.1	5.1
XI	7.0	as Control	8.1	oos[1]
XII	8.0	as Control	8.1	oos[1]
XIII	8.3	as Control	oos[1]	5.4
XIV	oos[1]	as Control	oos[1]	5.8
XV	9.0	as Control	7.2	6.3
XVI	8.7	as Control	7.2	6.1
XIX	8.1	as Control	7.8	6.6
XX	8.2	as Control	7.8	6.5
min	7.0	n.a.	7.2	5.1
max	9.0	n.a.	8.1	6.6

[1]oos = out of specs

As can be seen in table 6, the pH on discharge of the treated water was not fully recovered. The Principal did an independent pH-measurement with 3 sensors per tank. Measurements thereof averaged at pH 6 on discharge for all test runs (data from Coldharbour Marine not shown). This was in line with our own measurements and cross calibrations performed between the Principal's and MEA-nl's sensors. Therefore the very low average on discharge for test run X was attributed to a sensor malfunction.

Table 7: Average of temperature for individual runs at intake (T0) and discharge (T11)

Temperature °C				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	13.4	as Control	16.1	16.0
X	13.5	as Control	16.1	16.2
XI	14.5	as Control	19.5	19.2
XII	15.1	as Control	19.5	19.6
XIII	17.9	as Control	22.0	21.4
XIV	18.1	as Control	22.0	22.1
XV	18.5	as Control	22.2	22.3
XVI	18.4	as Control	22.2	22.7
XIX	19.7	as Control	18.7	18.4
XX	20.1	as Control	18.7	18.7
min	13.4	n.a.	16.1	16.0
max	20.1	n.a.	22.2	22.7

Neither the temperature range encountered during the certification tests (table 7), nor the lower temperatures encountered in the previous R&D tests (data not shown) did influence the system performance significantly. The salinity values in the brackish/marine region varied considerably during the test runs ranging from 19.8 to 34.6 PSU, thereby covering a broad range of salinity values (table 8). As with temperature, no influence on system performance was observed.

Table 8: Average of salinity (PSU) for individual runs at intake (T0) and discharge (T11)

salinity PSU				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	33.9	as Control	30.4	32.8
X	33.6	as Control	30.4	30.6
XI	32.9	as Control	29.3	30.6
XII	34.6	as Control	29.3	30.2
XIII	19.8	as Control	25.7	25.4
XIV	21.7	as Control	25.8	28.8
XV	31.8	as Control	30.9	29.6
XVI	32.5	as Control	30.9	31.5
XIX	30.5	as Control	30.8	30.3
XX	31.1	as Control	30.8	30.9
min	19.8	n.a.	25.7	25.4
max	34.6	n.a.	30.9	32.8

Table 9: Average of dissolved oxygen, in percentage saturation, for individual runs at intake (T0) and discharge (T11)

dissolved oxygen %				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	100.2	as Control	76.0	81.1
X	102.1	as Control	76.0	87.2
XI	103.7	as Control	60.8	83.8
XII	100.5	as Control	60.8	81.5
XIII	102.1	as Control	60.2	73.1
XIV	105.8	as Control	60.2	57.4
XV	113.7	as Control	55.3	84.9
XVI	114.7	as Control	55.3	79.8
XIX	97.4	as Control	83.4	93.9
XX	99.7	as Control	83.4	88.1
min	97.4	n.a.	55.3	57.4
max	114.7	n.a.	83.4	93.9

As can be seen in table 9, dissolved oxygen values in the treated tanks did not only recover due to re-aeration, prior to discharge, but normally exceeded the values of the control significantly (with the exception of test run XIV).

Table 10: Average of Total Suspended Solids (TSS) for individual runs at intake (T0) and discharge (T11)

TSS [mg/L]				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	77.4	as control	6.9	8.3
X	30.6	as control	6.9	12.5
XI	44.6	as control	5.8	7.2
XII	19.9	as control	5.8	8.2
XIII	53.4	as control	12.8	9.9
XIV	45.1	as control	12.8	10.5
XV	24.5	as control	5.3	7.2
XVI	16.2	as control	5.3	11.3
XIX	29.2	as control	5.4	12.6
XX	25.6	as control	5.4	18.9
min	16.2	n.a.	5.3	7.2
max	77.4	n.a.	12.8	18.9

As described before, the standard parameters were used to ensure that water masses were followed properly. However, table 10 shows that TSS values fluctuated widely even within one or two hours. TSS cannot easily be used to characterize a water body in shallow coastal waters. Even less so in the Wadden Sea with its system of deep gullies and mud-flats. Wave and wind action were sufficient to stir up substantial amounts of sediment. However, these were localized effects that did not alter the average properties of the intake water. A higher sampling frequency would not improve the definition of the intake water and to accept the high variability of this parameter. Looking at the data of paired test runs upon intake (when filling the tanks simultaneously) one finds the values for test run IX were two and a half times higher than for number X. Equally number XI was twice as high as number XII and number XV one-third higher than number XVI.

Table 11: Test results of Dissolved Organic Carbon (DOC) for individual runs at intake (T0), and discharge (T11). n.d.: not determined

DOC [mg/L]				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	2.1	as control	2.1	2.3
X	2.1	as control	2.1	1.9
XI	n.d.	as control	2.2	2.2
XII	n.d.	as control	2.2	2.1
XIII	2.9	as control	3.1	3.3
XIV	2.9	as control	3.1	3.1
XV	1.9	as control	1.8	2.3
XVI	n.d.	as control	1.8	1.9
XIX	2.8	as control	2.6	2.6
XX	2.8	as control	2.6	2.5
min	1.9	n.a.	1.8	1.9
max	2.9	n.a.	3.1	3.3

As for TSS, values of Dissolved Organic Carbon (DOC, table 11) were well below the recommended minimum concentration of 5 mg/L as required in guideline G8 (Anon., 2008). In terms of evaluating the BWMS's performance this was regarded not problematic. TSS can affect chemical systems due to reacting with an active substance and subsequently influencing the concentration thereof. The same can happen with DOC providing a reagent. Furthermore, TSS can influence UV based systems through absorption, influencing the energy transfer into the water. Both mechanisms were not applicable to the BWMS of Coldharbour Marine Ltd. Due to the elongated holding time it was argued that any manipulation of the ambient water leads to more ecological stress for the organisms. This was to be avoided in order to avoid extra mortality. In contrast to DOC and TSS, values for Particulate Organic Carbon (POC) were always above the requirements (table 12).

Table 12: Average of Particulate Organic Carbon (POC) for individual runs at intake (T0) and discharge (T11)

POC [mg/L]				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	25.2	as control	2.5	3.0
X	10.9	as control	2.5	4.1
XI	13.3	as control	2.3	2.7
XII	6.9	as control	2.3	3.4
XIII	14.4	as control	4.4	4.1
XIV	12.4	as control	4.4	4.2
XV	6.3	as control	2.1	3.0
XVI	5.7	as control	2.1	4.0
XIX	7.5	as control	1.8	4.1
XX	6.3	as control	1.8	6.2
min	5.7	n.a.	1.8	2.7
max	25.2	n.a.	4.4	6.2

Table 13: Average of turbidity measurements in NTU for individual runs at intake (T0) and discharge (T11)

Turbidity NTU				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	19.8	as Control	7.3	oos[1]
X	6.2	as Control	7.3	oos[1]
XI	4.3	as Control	2.3	oos[1]
XII	28.1	as Control	2.3	oos[1]
XIII	21.4	as Control	oos[1]	oos[1]
XIV	18.9	as Control	oos[1]	3.0
XV	46.9	as Control	oos[1]	13.9
XVI	42.8	as Control	oos[1]	oos[1]
XIX	oos[1]	as Control	oos[1]	oos[1]
XX	oos[1]	as Control	oos[1]	oos[1]
min	4.3	n.a.	2.3	3.0
max	46.9	n.a.	7.3	13.9

[1]oos = out of specs

The measurement of Nominal or Nephelometric Turbidity Units (NTU) is directly dependent on the composition of the fluid and the particles therein that are measured. Therefore it is more suited for, e.g. quality checks of known fluids (food products, waste water etc.) than for the measurement of highly variable natural waters. Subsequently the sensor used experienced difficulties, reflected in the high number of "oos"-readings seen in table 13.

4.2 BIOTIC PARAMETERS

4.2.1 ORGANISMS EQUAL TO OR LARGER THAN 50 MICRON IN CELL DIAMETER

As can be seen in table 14, numbers at intake were for the most part well above the requirements. Only the last two test runs (XIX and XX) were significantly lower. However, with average values being around 60,000 per cubic metre, numbers were sufficient to evaluate system performance. After 11 days, more than double the holding time required in guideline G8 (Anon., 2008), survival in the control tanks was substantially higher than required.

The average of test run XI was 11,7 per cubic metre. Formally, this was above the discharge standard. However, looking at the standard error of the number ten (7 to 13) and the 95% confidence interval, resulting in a maximum of 15, this number would be acceptable. Moreover, the systematic failure of the sampling and analysis method applied was approx. 10%. Therefore, it is scientifically not possible to determine if this run was a pass or a fail. Taking into account the indirect evidence available, it was decided to treat the run as pass. This interpretation was based on a number of arguments. Firstly, the type of organisms found (barnacle cypris larvae) that were present in the samples alive/dying (reduced motility) and dead were not the dominant group (including in the analysis the earlier nauplia stages). Therefore their presence was not based on statistical chance but the result of a treatment effect. Secondly, the status (motility and mobility) of the organisms encountered. Guideline G8 (Anon., 2008) required living organisms to be counted as viable. With regards to ease of reference and later compliance control outside a laboratory setting, this was understandable. However, this definition was not according to the scientific definition of viability. At least a quarter of the encountered barnacle larvae was counted based on internal movement, after observing them in excess of 30 seconds. Other than that they did not show behavioural responses to physical manipulation, making it highly likely that they were dying. Furthermore the system’s performance in the other test runs (including R&D) was taken into account. The paired run XII, which was filled simultaneously with XI and therefore had the same intake conditions (biotic and abiotic) was a pass. This further indicated the ability of the system to treat barnacle larvae successfully.

Table 14: Average number of organisms larger than 50 micron of individual runs at intake (T0) and discharge (T11)

Organisms > 50 um				
Test run	Control T0	Treated T0	Control T11	Treated T11
IX	134,300.0	as control	23,816.7	10.3
X	94,450.0	as control	as IX	1.3
XI	123,100.0	as control	34,750.0	11.7
XII	103,050.0	as control	as XI	6.3
XIII	133,400.0	as control	20,900.0	4.3
XIV	137,466.7	as control	as XIII	2.3
XV	115,666.7	as control	6,583.3	0.0
XVI	130,250.0	as control	as XVI	1.3
XIX	61,733.3	as control	12,050.0	9.3
XX	59,050.0	as control	as XIX	1.3
min	59,050.0	n.a.	6,583.3	0.0
max	137,466.7	n.a.	34,750.0	11.7

4.2.2 ORGANISMS SMALLER THAN 50 MICRON BUT LARGER THAN 10 MICRON IN CELL DIAMETER

This size class includes most phytoplankton organisms and microzooplankton, such as ciliates and dinoflagellates.

Table 15: Test results of phytoplankton numbers larger than 10 micron of individual runs at intake (T0), and discharge (T11) of control (C) and treated water (T). C+T-inc-Tx1 = incubation of intake water under optimal growth conditions for a period of days given in column Tx1; C-dis-Tx2 and T-dis-Tx2 = incubation of discharge water under optimal growth conditions for a period of days given in column Tx2

large(>10 micron) count/ml								
Test run	C+T-T0	C+T-inc-Tx1	C-T11	T-T11	C-dis-Tx2	T-dis-Tx2	Tx1 [days]	Tx2 [days]
IX	1,706	719	6.7	147.9	129.2	34.9	6	9
X				56.2				
XI	3,531		23.2	67.1	106.2	141.4		
XII	822			55.3		248.2		10
XIII	6,189	790	11.6	212.1	282.9	31.4	5	16
XIV				189.6				
XV	3,077	127	0.8	119.9	46.2	1.5	11	8
XVI				85.6				
XIX	444	683	7.1	79.8	205.5	29.2	12	9
XX				43.2		3.1		9
average	2,628.0	579.9	9.9	105.7	154.0	70.0	n.a.	n.a.
min	443.8	127.4	0.8	43.2	46.2	1.5	n.a.	n.a.
max	6,188.5	790.2	23.2	212.1	282.9	248.2	n.a.	n.a.

Phytoplankton numbers at intake were for most test runs, well above the minimum required number of 1000 per mL (table 15). A holding period of 11 days in the dark resulted in a substantial decrease of phytoplankton in the control tank. Numbers of phytoplankton cells larger than 10 micrometer in the control tank were always significantly lower than in the treated tank. This can be explained by grazing in the control tank, while in the treated tank the grazers had been eliminated (cf. section 4.2.1, table 14).

At discharge chlorophyll containing particles larger than 10 micrometer were still present in the treated water (table 15). These results were due to fragments, larger chains or clusters of smaller particles and debris. Measurements of the photosynthetic efficiency (table 16) indicated that these chlorophyll containing particles possessed no active photosynthesis and should be considered as non-viable. At test run XIII the measurement was not immediately conclusive (exceeding the threshold of 0.1). However, as can be seen from the results of the incubation experiment on this test run, no recovery of phytoplankton took place.

Table 16: Test results of phytoplankton photosynthetic efficiency (Fv/Fm) of the total phytoplankton community (2 – 50 micron size range) of individual runs at intake (T0), and discharge (T11) of control (C) and treated water (T). C+T-inc-Tx1 = incubation of intake water under optimal growth conditions for a period of days given in column Tx1; C-dis-Tx2 and T-dis-Tx2 = incubation of discharge water under optimal growth conditions for a period of days given in column Tx2

<table>
<tr><th colspan="9">Fv/Fm phytoplankton photosynthetic efficiency</th></tr>
<tr><th>Test run</th><th>C+T-T0</th><th>C+T-inc-Tx1</th><th>C-T11</th><th>T-T11</th><th>C-dis-Tx2</th><th>T-dis-Tx2</th><th>Tx1 [days]</th><th>Tx2 [days]</th></tr>
<tr><td>IX</td><td rowspan="2">0.499</td><td rowspan="2">0.479</td><td rowspan="2">0.009</td><td>0.072</td><td rowspan="2">0.585</td><td>0.000</td><td>6</td><td>9</td></tr>
<tr><td>X</td><td>0.042</td><td></td><td></td><td></td></tr>
<tr><td>XI</td><td>0.595</td><td rowspan="2"></td><td rowspan="2">0.097</td><td>0.050</td><td rowspan="2">0.468</td><td>0.000</td><td></td><td></td></tr>
<tr><td>XII</td><td>0.612</td><td>0.000</td><td></td><td></td><td>10</td></tr>
<tr><td>XIII</td><td rowspan="2">0.599</td><td rowspan="2">0.541</td><td>0.214</td><td>0.157</td><td rowspan="2">0.469</td><td>0.000</td><td>5</td><td>16</td></tr>
<tr><td>XIV</td><td>0.598</td><td>0.000</td><td></td><td></td><td></td></tr>
<tr><td>XV</td><td rowspan="2">0.585</td><td rowspan="2">0.611</td><td rowspan="2">0.000</td><td>0.000</td><td rowspan="2">0.526</td><td>0.000</td><td>11</td><td>8</td></tr>
<tr><td>XVI</td><td>0.000</td><td></td><td></td><td></td></tr>
<tr><td>XIX</td><td rowspan="2">0.608</td><td rowspan="2">0.645</td><td rowspan="2">0.000</td><td>0.000</td><td rowspan="2">0.390</td><td>0.000</td><td>12</td><td>9</td></tr>
<tr><td>XX</td><td>0.000</td><td>0.000</td><td></td><td>9</td></tr>
<tr><td>average</td><td>0.583</td><td>0.569</td><td>0.153</td><td>0.032</td><td>0.488</td><td>0.000</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>min</td><td>0.499</td><td>0.479</td><td>0.000</td><td>0.000</td><td>0.390</td><td>0.000</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>max</td><td>0.612</td><td>0.645</td><td>0.598</td><td>0.157</td><td>0.585</td><td>0.000</td><td>n.a.</td><td>n.a.</td></tr>
</table>

Table 17: Average number of microzooplankton for individual runs at intake (T0) and discharge (T11)

Microzooplankton/ ml			
Test run	Control T0	Control T11	Treated T11
IX	1.80	0.25	0.03
X	1.80	0.25	0.09
XI	0.34	0.03	0.06
XII	0.34	0.03	0.00
XIII	0.52	0.06	0.00
XIV	0.52	0.06	0.00
XV	1.36	0.00	0.12
XVI	1.36	0.00	3.82
XIX	1.20	0.13	0.27
XX	1.20	0.13	0.03
min	0.34	0.00	0.00
max	1.80	0.25	3.82

Organism numbers for microzooplankton were already low on intake and decreased further during the holding time of eleven days. The low abundance on intake in combination with the statistical error of sampling and measurement made a separate analysis for this group of organisms not suitable. As can be seen from tables 15 and 17, microzooplankton was of minor importance as compared to phytoplankton.

The tests showed that phytoplankton was of more concern than the large zooplankton. This was a slightly unexpected outcome, since initially the lack of a filter was thought to be problematic, while phytoplankton was thought to be killed mostly through elongated exposure to darkness. The system was tested against intake numbers of organisms well above the requirements. It proved to be capable of treating resilient zooplankton organisms such as barnacle cypris larvae. The latter being able to survive chlorine exposure of more than 2 ppm for 5 days (research data not shown). In contrast, survival of phytoplankton in the initial R&D tests was well above the discharge standard and significantly higher than in the control. In the latter the phytoplankton was subject to grazing from the zooplankton. As can be seen in tables 15 and 16, the system settings were eventually optimized as to treat phytoplankton consistently as well. For the last two test runs performed, intake numbers were lower than required. Having finished eight test runs with high organism densities and healthy populations as was shown by control survival (table 14 and 15) this was acceptable from a biologist's and statistics point of view.

4.2.3 BACTERIA AND HUMAN PATHOGENS (INDICATOR MICROBES)

Table 18: Results of total number of E. coli in colony forming units (CFU) per 100 mL for intake (T0) and discharge (T11). n.d. = not determined

E. coli					
Test run	Challenge	Control T0	Treated T0	Control T11	Treated T11
IX	<1	as challenge	as control	<1	<1
X	<1	as challenge	as control	<1	<1
XI		n.d.	n.d.	<1	<1
XII		n.d.	n.d.	<1	<1
XIII	n.d.	n.d.	n.d.	n.d.	n.d.
XIV	n.d.	n.d.	n.d.	n.d.	n.d.
XV	<1	<1	as control	<1	<1
XVI	<1	<1	as control	<1	<1
XIX		<1	as control	<1	<1
XX		<1	as control	<1	<1
min	n.a.	n.a.	n.a.	n.a.	n.a.
max	n.a.	n.a.	n.a.	n.a.	n.a.

Table 19: Results of total number of enterococci in colony forming units (CFU) per 100 mL for intake (T0) and discharge (T11). n.d. = not determined

enterococci					
Test run	Challenge	Control T0	Treated T0	Control T11	Treated T11
IX	<1	as challenge	as control	<1	<1
X	<1	as challenge	as control	<1	<1
XI		n.d.	n.d.	<1	3,0
XII		n.d.	n.d.	<1	<1
XIII	n.d.	n.d.	n.d.	n.d.	n.d.
XIV	n.d.	n.d.	n.d.	n.d.	n.d.
XV	<1	<1	as control	<1	<1
XVI	<1	<1	as control	<1	<1
XIX		<1	as control	14.0	3.0
XX		<1	as control	14.0	<1
min	n.a.	n.a.	n.a.	n.a.	n.a.
max	n.a.	n.a.	n.a.	14.0	3.0

The presence of IMO D2-Standard relevant human pathogens remained below the detection limit already in the challenge water (tables 18 and 19). In test runs XIX and XX some enterococci were detected. Values were below the discharge standard (IMO, 2004) in the control already. The effectiveness of the Coldharbour BWMS in terms of reducing the number of human pathogens can therefore not be determined on basis of the present outcome.

Table 20: test results of total bacteria number (based on DNA containing particles per mL) of individual runs at intake (T0) and discharge (T11)

total bacteria number/mL				
Test run	Challenge	Control & Treated T0	Control T11	Treated T11
IX	9.0E+06	1.4E+07	8.7E+06	1.2E+07
X				1.1E+07
XI	8.4E+06	8.6E+06	6.9E+06	6.8E+06
XII				8.0E+06
XIII	1.0E+07	1.0E+07	7.4E+06	7.2E+06
XIV				8.0E+06
XV	1.0E+07	1.1E+07	2.8E+06	2.9E+06
XVI				3.0E+06
XIX	6.9E+06	6.6E+06	4.5E+06	5.2E+06
XX				8.2E+06
average	9.0E+06	1.0E+07	6.1E+06	7.2E+06
min	6.9E+06	6.6E+06	2.8E+06	2.9E+06
max	1.0E+07	1.4E+07	8.7E+06	1.2E+07

Total bacteria numbers (table 20) were orders of magnitude above the minimum number as required by guideline G8 (Anon., 2008). On average the 11 day holding period of the control water resulted in a decrease in bacteria numbers. Compared to the control the disinfection treatment did not affect the bacteria population in term of total number present.

4.2.4 PLANKTON DIVERSITY CHALLENGE WATER

The biodiversity of the plankton in the larger than 50 micron as well as in the 10 to 50 micron size range was in accordance with the requirements of 5 different species of at least 3 different phyla (Anon., 2008).
For the size class larger than 50, 23 different species from 9 phyla could be identified. The zooplankton-organisms belonged to the following phyla: Rotatoria, Plathelminthes, Annelida, Mollusca, Nematoda, Arthropoda, Echinodermata and Chordata. Additionally, large diatoms (e.g. Coscinodiscus) were encountered.
In the size class smaller than 50, ciliates were present in the microscopic samples. Phytoplankton was analysed using flow cytometry and no separate species determination was conducted. Therefore no exact number of species or higher groups can be presented here. However, the diversity of smaller plankton in the Wadden Sea is well documented. The natural assemblage is highly variable with at least 50 different species present on a regular basis.

5 SUMMARY AND CONCLUSIONS

From June 14th until September 9th 2013 a total of 10 verification test runs was conducted by MEA-nl on the BWMS of Coldharbour Marine Ltd.

The BWMS of Coldharbour Marine Ltd. differed from the majority of existing BWMS's in two ways. It does not include a filtration step and it is an in-tank treatment system, whilst the majority of systems having Type Approval already, perform in-line treatment. This combination of factors makes its performance independent of the flow-rate and also suitable for gravity ballasting. Due to the holding time of 11 days during the tests, it also makes the system unsuitable for short voyages, as it requires several days to treat the water.

MEA-nl did not manipulate the test water and all test runs were performed with the natural water composition. This caused the system to be tested in a wide range of conditions. In turn it did also cause intake values for some parameters to be below the requirements of guideline G8 (Anon., 2008) in a number of test runs. This was not considered critical for the verification of the system's performance.

Abiotic prameters
The pH upon intake was usual around 8, the normal value for brackish and marine waters. The temperature range encountered during intake was 13.4°C to 20.1°C and salinity was between 19.8 PSU and 34.6 PSU. The challenge water at intake In all test runs the intake water was saturated with oxygen. Values for total suspended solids ranged from 16.2 mg/L to 77.4 mg/L and particulate organic carbon from 5.7 mg/L to 25.2 mg/L. Values for dissolved organic carbon were between 1.9 mg/L and 2.9 mg/L. NTU is not well suited for the measurement of fluids with a highly variable composition. Therefore the sensors used read out of specs rather frequently. The measurements that were taken ranged from 4.3 NTU to 46.9 NTU. Intake numbers for organisms were mostly well above the requirements.
Upon discharge dissolved oxygen values of treated water were higher than those of the control due to the aeration. However, pH did not recover and remained 1 to 1.5 lower than in the control water. The possible effects of this were not investigated in this study, but in a separate toxicological study (IMARES, 2010).

Biotic parameters
Organism numbers on discharge were in compliance with regulation D-2 (IMO, 2004). Results for organisms larger than 50 micrometre ranged from 0.0 to 11.7 organisms per cubic metre, with an average of 4.8 living organisms per cubic metre. Organism numbers in the size class 10 – 50 micrometre were below 10 in all cases. Flow cytometry and PAM measurements do not yield discrete numbers of living organisms. Therefore no range and average were determined for this size class. The presence of relevant human pathogens remained below the detection limit already in the challenge water. The effectiveness of the Coldharbour BWMS in terms of reducing the number of human pathogens can therefore not be determined on basis of the present outcome.

In conclusion, the performance of the system throughout the verification testing presented in this report, showed it to be a viable system, capable of treating ballast water to the requirements of regulation D-2 (IMO, 2004).

6 QUALITY ASSURANCE

MEA-nl is a test organization with clear policies and procedures described in the Quality Management System based on NEN-EN-ISO 9001:2008 (further referred as ISO 9001). Quality is crucial for MEA-nl at all operational levels. All products and services are based on the same quality according to ISO 9001. MEA-nl assures that all analytical methods done at external labs are done conform at least the same quality requirements as MEA-nl.

Quality of measurements and data acquisition is guaranteed by having a standard operating procedure (SOP) for every method and measurement needed to verify the performance of a BWT system. SOPs are part of our Quality Management System, assuring that measurements are transparent and easily reproducible, irrespective of which trained personnel is performing the measurement. Methods are all based on well-established scientific procedures. All sampling and analysis needed to verify a BWMS are done by well trained and experienced personnel. Test results will be recorded at forms or notebooks specified in SOPs.

Besides data in general, non-conformities such as deviations and out of specs are crucial to assure data reliability. Based on MEA-nl related activities, different non-conformities occurred during the verification tests of the BWMS of Coldharbour Marine Ltd. All these non-conformities are solved following our Quality Management System and did not affect the results of the verification tests of Coldharbour Marine Ltd.

No complaints were received during the whole process until this moment. Based on this report a last customer satisfaction verification will be done to finalize this process and to assure that all procedures and processes were done conform the customer requirements. With this information MEA-nl tries to facilitate future improvements and development.

7 GLOSSARY OF TERMS AND ABBREVIATIONS

7.1 GLOSSARY OF TERMS

Accreditation: the meaning assigned to it by Regulation (EC) No 765/2008.

Active Substance means a substance or organism, including a virus or a fungus that has a general or specific action on or against Harmful Aquatic Organisms and Pathogens

Amendment: is a change to a specific verification protocol or a test plan done before the verification or test step is performed.

Ambient Populations: The biological organisms, including bacteria, protists, and zooplankton that are naturally occurring in the water at the TF location.

The Ballast Water Management Plan: the document referred to in Regulation B-1 of the Convention describing the ballast water management process and procedures implemented on board individual ships.

Ballast Water Treatment Equipment: equipment which mechanically, physically, chemically, or biologically processes, either singularly or in combination, to remove, render harmless, or avoid the uptake or discharge of Harmful Aquatic Organisms and Pathogens within Ballast Water and Sediments. Ballast Water Treatment Equipment may operate at the uptake or discharge of ballast water, during the voyage, or at a combination of these events.

Challenge Water: Water supplied to a treatment system under test. Challenge water must meet specified ranges for living organism densities and water quality parameters and is used to assess the efficacy of the treatment equipment under full-scale operational conditions.

Comparability: The measure of the confidence with which one data set can be compared to another.

Cyst: The dormant cell or resting stage of microalgae, heterotrophic protists, and metazoans, including but not limited to cysts of dinoflagellates, spores of diatoms, cysts of heterotrophic protists, and cysts of rotifers.

Deviation: is a change to a specific verification protocol or a test plan done during the verification or test step performance (EC).

Effluent: The treated discharge water produced by a ballast water treatment system.

Equipment: The ballast water treatment system, defined as either a package or a modular system, which is to be tested for Type Approval.

General verification protocol (GVP): means the description of the principles and general procedure to be followed by the ETV pilot programme when verifying an individual environmental technology.

In-Line Treatment: A treatment system or technology used to treat ballast water during normal flow of ballast during uplift or discharge.

Land-based Testing: a test of the BWMS carried out in a laboratory, equipment factory or pilot plant including a moored test barge or test ship, according to Parts 2 and 3 of the Annex to these Guidelines, to confirm that the BWMS meets the standards set by Regulation D-2 of the Convention

Manufacturer: A business that manufactures, assembles, or sells ballast water treatment technologies.

Monitoring Equipment: the equipment installed for the assessment of the effective operation of the Ballast Water Treatment Equipment.

Performance Data: Removal efficacy and effluent concentration data for core and supplemental parameters for a given set of Challenge conditions.

Performance claim: means a set of quantified technical specifications representative of the technical performance and potential environmental impacts of a technology in a specified application and under specified conditions of testing or use (operational parameters)..

Precision: The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, or range, in either absolute or relative terms (NELAC, 1998).

Protocol: A written document that clearly states the objectives, goals, scope, and procedures for the study of a particular group of similar technologies. A protocol shall be used for reference during manufacturer participation in the verification testing program.

Quality Assurance Project Plan (QAPP): A written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project (also see Test/quality assurance plan).

Representativeness: The degree to which data accurately and precisely represent a characteristic of a population.

Sensitivity: The capability of a test method or instrument to discriminate between different levels (e.g., concentrations) of a variable of interest.

Standard Operating Procedure (SOP): A written document containing specific instructions and protocols to ensure that quality assurance requirements are maintained.

Test Cycle: One fill/discharge cycle (including appropriate holding periods) designed to gather data on treatment efficiency.

Test Facility: A site that provides the necessary infrastructure, systems and (scientific) personnel to complete the land-based testing for Type Approval. The facility may be part of the Testing Organization or may be independent from the Testing Organization, but in any case shall be totally independent from technology manufacturers testing at their site.

Test/Quality Assurance Plan (TQAP): Also called a Quality Assurance Project Plan (QAPP), this is a written document that describes the procedures for conducting a test or study according to the verification protocol requirements for the application of a particular ballast water treatment system at a particular site. At a minimum, the TQAP shall include detailed instructions for sample and data collection, sample handling and preservation, precision, accuracy, goals, and quality assurance and quality control requirements relevant to the particular site.

Testing Organization (TO): An organization qualified to conduct studies and testing of ballast water treatment technologies in accordance with protocols and TQAPs.

The Convention: the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO).

Treatment Rated Capacity (TRC): the maximum continuous capacity expressed in cubic metres per hour for which the BWMS is type approved. It states the amount of ballast water that can be treated per unit time by the BWMS to meet the standard in regulation D-2 of the Convention.

Verification: The establishment of evidence on the performance of a ballast water treatment system under specific conditions, following a predetermined study protocol(s) and TQAP(s).

Verification: means the provision of objective evidence that the technical design of a given environmental technology ensures the fulfilment of a given performance claim in a specified application, taking any measurement uncertainty and relevant assumptions into consideration (EU).

Verification Organization (VO): The party responsible for overseeing TQAP development, overseeing testing activities in conjunction with the Testing Organization, and overseeing the development and approval of the Verification Protocol, Report and Verification Statement for the ballast water treatment system. In general National Administration or a Classification Society authorised by the NA.

Verification Report: A detailed report on the testing results of a particular technology according to an approved Test /Quality Assurance Plan and conducted under the ETV/GTV protocol. The report is typically prepared by the TO and contains a description of the test facility, photographs of technology being tested methods and procedures, presentation of analysed data including all QA/QC data obtained during the test. Appendices include raw data sets and lab audit information, TQAP, O&M Manual and other relevant information.

Verification Statement: An executive summary of the verification report. A summary of the data will be part of Type Approval Certificate.

Verification Test: A complete test of a treatment system, following a well-defined TQAP which includes enumeration of ambient and test populations in the challenge water to determine the efficacy of the technology.

Viable: According to the IMO G8 guidelines, "organisms and any life stages thereof that are living". This differs to the scientific definition, "organisms which are capable of reproducing".

Vital: essential to the continuation of life

7.2 ABBREVIATIONS AND ACRONYMS

BWM	Ballast Water Management
BWMS	Ballast Water Management system(s)
m^3	cubic meter, equivalent to 1000 Litres
DOC	Dissolved organic carbon
GVP	General Verification Protocol (EU Environmental Technology Verification pilot programme
IMO	International Maritime Organization (http://www.imo.org)
µg/L	micrograms per litre
mg/L	milligrams per litre
MM	Mineral Matter
n.a.	not applicable
n.d.	not determined
NTU	Nephelometric/Nominal turbidity unit
PSU	Practical salinity units
QA	Quality Assurance
SOP	Standard Operating Procedure
TSS	Total Suspended Solids

8 REFERENCES

Anonymous (2008) Guidelines for approval of ballast water management systems (G8). Annex 2 Resolution MEPC.174.58)

Anonymous (2011) General Verification Protocol (EU Environmental Technology Verification pilot programme) Version 1.0 December 15th, 2011

Anonymous (2012) Generic protocol for the verification of the ballast water treatment technology of Coldharbour Marine Ltd.

IMARES (2010) Toxicity tests with ballast water produced by Inert Gas Stripping. Report number C163/10

IMO (2004) International convention for the control and management of ship's ballast water and sediments, 2004

8.1 STANDARD OPERATION PROCEDURES (SOP'S) OF MEA-NL

SOP-306: 30.09.2013; version-number 1.1

SOP-308: 26.09.2012; version-number 1.0

SOP-311: no date; version-number 0.1

SOP-316: 26.09.2012; version-number 1.0

SOP-317: 26.09.2012; version-number 1.0

SOP-318: 26.09.2012; version-number 1.0

SOP-319: 26.09.2012; version-number 1.0

SOP-320: 26.09.2012; version-number 1.0

SOP-322: 26.09.2012; version-number 1.0